Coastal Engineering Technical Note

GEOTECHNICAL SAMPLING GUIDELINES FOR RUBBLEMOUND COASTAL STRUCTURES

PURPOSE: To provide guidance in developing soil sampling programs for rubblemound coastal structures.

BACKGROUND: While there are many different types of coastal structures, a large percentage of these structures are rubblemound; i.e., jetties or breakwaters, placed on shallow foundations. The sampling guidelines discussed in this technical note are focused on geotechnical considerations for these structures.

Rubblemound structures are generally designed in two steps. First the structures is designed to perform its function. For example, breakwaters are designed to reduce wave energy. Second, the structure must be designed so the soil supporting the structure will not fail in shear nor by excessive settlement, which reduces the functional effectiveness of the structure. Rubblemound structures are usually flexible and can accept some differential settlement.

To economically and safely design a rubblemound structure, key properties of the soil below it must be known, such as, shear strength, angle of internal friction, and compressibility. These can be determined by in situ testing or laboratory testing of appropriate soils samples. Sampling in cohesive soil must include sufficient "undisturbed" samples for the planned testing program. In an "undisturbed" sample there presumably has been so little disturbance of the material that it can be laboratory tested for in situ properties such as strength, consolidation, and permeability. Such samples of cohesive soils can be obtained with today's techniques and equipment.

GUIDELINES: One of the most important points to remember when planning a sampling program is flexibility. Size and cost of the sampling program should be matched to the project size, cost, and risk to life and property due to failure of the project. Sensitivity of the structure to settlement and cost of repair if excessive settlement occurs should be considered in designing the

sampling program. Sampling and testing programs should be planned by, or with the advise of, qualified geotechnical engineers. Sampling programs are usually divided into three phases: (1) reconnaissance, (2) preliminary exploration, and (3) detailed design exploration. A description of various geotechnical testing procedures is found in EM 1110-2-1907 (US Army, 1972).

RECONNAISSANCE: This phase consists of a review of all available topographic and bathymetric charts, aerial photographs, and geological information for the site. Field investigations of the site and a review of performance of existing structures in the area also are accomplished in this phase. The reconnaissance survey provides the information needed to establish the number and location of preliminary borings and whether geophysical methods should be used.

PRELIMINARY EXPLORATION: In the preliminary exploration phase the approximate depth, thickness, and composition of the various soil strata should be determined along with the ground water level, depth to the soil, rock or other firm material interface and estimates of critical geotechnical parameters needed for preliminary design. These parameter estimates include shear strength, friction angle, and compressibility. Geophysical methods, usually seismic reflection in water and seismic refraction on land, are often part of the preliminary exploration. Both methods are described in EM 1110-2-1908 (US Army, 1971). Seismic surveys are useful in locating geologic nonconformities which have no apparent surface expression, such as old channels filled with soft silt beds or old lagoonal deposits now covered with thin sand layers. Geophysical methods are most effective when combined with a sampling procedure that provides samples for identification of soil type and some measurement for correlation to in situ shear strength. In cohesionless soil the blow count from the penetration of a split spoon sampler may be used to estimate shear strength. In cohesive soils, vane shear or cone penetrometer devices may be used to measure shear strength.

In specifying spacing of bore holes for the preliminary exploration phase, the engineer should consider the type and size of structure, the nature of the sub-soils, and the implications of possible in situ soil conditions to the project's feasibility and design concepts. For sites where structures will be on soft cohesive soils, close (100 to 400 ft) spacings are reasonable. Wider spacings (300 to 600 ft) may be used for uniform stiff over consolidated clay, (EM 1110-1-1804, 1982). In both cases, samples from adjacent holes should be correlated for evidence of subsurface changes or anomalies and additional bore

holes, sufficient to develop adequate understanding of the subsurface stratigraphy, should be specified when such anomalies occur. EM-1110-1-1804 contains a full discussion of sampling.

It is often more economical to take some undisturbed samples of cohesive soils during the preliminary boring because of the high cost of mobilizing and demobilizing a sampling barge. Two holes can be sampled at each location (one on each side of the barge). Disturbed spit spoon samples are taken first. A geotechnical engineer, on board or in direct communication with the driller, can analyze the disturbed samples and decide at what depths a limited number of undisturbed samples are needed to fully characterize the cohesive layers. Vane shear tests taken at the same layers may be used to correlate fully sampled layers with other boring logs.

DETAILED DESIGN EXPLORATION: When a detailed follow-on soil exploration program is needed, it is appropriate to consider it as a means of filling in necessary data on critical layers or subsurface discontinuities not available from the preliminary results.

A successful detailed sampling program will adequately fill in the preliminary description of the foundation soils discussed above. Testing in this phase should be aimed at answering specific data needs for design. The value of additional testing must be weighted against its cost. For instance, when the earlier phases have revealed an erratic soil profile, i.e., old marsh deposits, borings with a spacing of 25 to 50 ft may be required in the vicinity of such discontinuities. But for very erratic profiles, extensive testing may not be justified. Usually the design in such cases is based on the conditions found in the weakest soil layer, or on an average of the conditions.

The depth to which the soil bore holes should be taken is a function of both the estimates surcharge load caused by the project and in situ soil profile. Terzaghi and Peck (1967) stress that the necessary depth of sampling is primarily dependent on the presence of soft compressible layers in the soil profile. Such a layer of soft clay may cause objectionable settlements even when well below the bottom of the structure. The method suggested by Terzaghi and Peck for establishing the recommended depth of boring is to make an estimate of the vertical normal stress distribution induced in the subsoil by the project loads, and based on this estimate determine the maximum depth at which these loads will cause a significant stress increase. Formulas for calculating these

depths can be found in Smith (19'70) or many geotechnical notebooks. When a subsoil profile contains only sand layers, the data from sampling to depths of about 30 ft is generally sufficient to estimate performance.

CONSTRUCTION MONITORING: Frequently, completion of the design and soil exploration activities occur about the same time. The soil profile assumed during the design phase is frequently not representative of actual site conditions. If assumptions are not corrected, the design can result in a misleading stability analysis. Observation of the structure's performance and the foundation soil's reaction to loading should not only extend through construction, but periodically throughout the life of the structure. However, like all phases of geotechnical investigation, the level of monitoring should be proportioned to project size, probability of condition changes, and risk of damage.

In general, a monitoring program during construction should be instituted to verify the anticipated soil profile or to discover deviations from this profile, and to provide data for determining their impact on the project. Installing settlement plates, piezometers, and inclinemeters to monitor the time rate of consolidation of the soil and any lateral displacement permits the engineer to estimate when settlement prediction are within acceptable limits. Detailed discussion of project monitoring is found in EM lllO-2-XXXX (US Army, 1988).

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REFERENCES: Hvorslev, M. J. 1949. *'Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes,11 USACE Waterways Experiment Station, Vicksburg, MS, (Reprinted by the Engineering Foundation, 1962, 1965 obtain via ASCE.

Smith R. E. Mar 1970. "Guide for Depth of Foundation Exploration," Journal of the Soil Mechanics and Foundations Div., ASCE, Vol. 96, No. SM2, pp. 377-384.

Terzaghi, K., and Peck, R. B. 1967. "Soil Mechanics in Engineering Practice," Second Editions, John Wiley and Sons, Inc., NY.

US Army. May 1971. 'Geophysical Exploration," EM 1110-l-1802, US Government Printing OfPlce, Washington, DC.

US Army. 1972. "Engineering and Design-Soil Sampling," EM 1110-2-1907, US Government Printing Office, Washington, DC.

US Army. Sep 1981. "Geotechnical Investigation for Civil Works and Military Construction,"EM 1110-I-1804. US Government Printing Office, Washington, DC.

US Army. 1988 (in preparation). "Coastal Project Monitoring," EM- lllO-Z-XxXx, US Government Printing OPPice, Washington, DC.